Minimal Walking Technicolor Spectroscopy

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Standard Model

$$\mathcal{L}_{SM} = \mathcal{L}_G + \mathcal{L}_F + \mathcal{L}_H$$

$$\mathcal{G}_{SM} = SU(3)_C \times SU(2)_I \times U(1)_Y$$
$$\downarrow$$
$$\mathcal{G}_{obs} = SU(3)_C \times U(1)_{EM}$$

SM minus Higgs

$$\mathcal{L} = \mathcal{L}_G + \mathcal{L}_F$$

$$\mathcal{G} = SU(3)_C \times SU(2)_I \times U(1)_Y$$

$$\mathcal{L}_C + \mathcal{L}_q \to \mathcal{L}_\chi = \frac{f^2}{4}\mathrm{Tr}[(D^\mu\Sigma)^\dagger D_\mu\Sigma]$$

$$D_\mu\Sigma = \partial_\mu\Sigma - i\frac{g}{2}\tau^a A^a_\mu\Sigma + i\frac{g'}{2}\Sigma\tau^3 B_\mu$$

$$\Sigma = \exp\left(\frac{2i}{f}\tau^a\pi^a\right)$$

DEWSB

$$|D_\mu \Sigma|^2 = \frac{g^2}{4}\left(A'^a_\mu - \frac{4}{fg}\partial_\mu \pi^a\right)^2$$

$$(A')^a_\mu = \left(A^1_\mu, A^2_\mu, A^3_\mu - \frac{g'}{g}B_\mu\right)$$

$$W^a_\mu \equiv A'^a_\mu - \frac{4}{fg}\partial_\mu \pi^a$$

$$Z_\mu \equiv \frac{g}{\sqrt{g^2 + g'^2}} W^3_\mu$$

$$\mathcal{G} = SU(3)_C \times SU(2)_I \times U(1)_Y \to SU(3)_C \times U(1)_{EM}$$

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QCD$\times 10^3$

Can we use this mechanism at the GeV scale?

$$\mathcal{G}_{TC} = \mathcal{G}_{SM} \times SU(N_T)$$

- N_D techniquark pairs (U, D)
- Becomes strong at Λ_{TC} ~100 GeV

$$\langle \bar{T}_{iL} T_{jR} \rangle \sim \delta_{ij} \Lambda^3_{TC}$$

$$F_T \sim \sqrt{\frac{N_T}{3}} \left(\frac{\Lambda_{TC}}{\Lambda_{QCD}} \right) f_\pi$$

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Extended Technicolor

Except! $m_{q,l} = 0$

$$\mathcal{G}_{ETC} \supset \mathcal{G}_{TC}$$

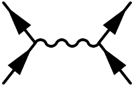
α: $\bar{T}\gamma_\mu T$

$$F_T^2 M_{\pi_T}^2 \simeq 2m_T(M_{ETC})\langle \bar{T} T\rangle_{ETC}$$

β: $\bar{T}\gamma_\mu q$

$$m_{q,l}(M_{ETC}) \sim \frac{1}{\Lambda_{ETC}^2}\langle \bar{T} T\rangle_{ETC}$$

γ: $\bar{q}\gamma_\mu q$



$$2M_K^0 \Delta M_K(M_{ETC}) = \frac{Re(\gamma_{sd}^2)}{2\Lambda_{ETC}} f_k^2 M_K^2$$

$$S \simeq N_D \frac{d(R)}{6\pi}$$

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Condensate

- Masses from ETC depend on

$$\langle \bar{T} T \rangle_{ETC} = \langle \bar{T} T \rangle_{TC} Z(\Lambda_{TC}, \Lambda_{ETC})$$

$$Z(\Lambda_{TC}, \Lambda_{ETC}) = \exp\left(\int_{\Lambda_{TC}}^{\Lambda_{ETC}} \frac{d\mu}{\mu} \gamma(\mu) \right)$$

- Before assumed $\gamma(\mu) \sim \alpha_{TC}(\mu) \to 0$ for $\mu > \Lambda_{TC}$ and so $Z \sim 1$
- If γ constant between Λ_{TC}, Λ_{ETC} then

$$Z \sim \left(\frac{\Lambda_{ETC}}{\Lambda_{TC}} \right)^{\gamma} \tag{1}$$

What walks?

$$\beta(g) = -\beta_0 g^2 - \beta_1 g^3$$

$$\beta_0 = \frac{1}{4\pi}\left(\frac{11}{3}N_c - \frac{4}{3}T(R)N_f\right)$$
$$\beta_1 = \frac{1}{(4\pi)^2}\left[\frac{34}{3}N_c^2 + \left(\frac{1}{N_c} - \frac{13}{3}N_c\right)N_f\right]$$

Three possibilities:

- QCD-like
- Walking
- Conformal

Suggested that conformal theories would also serve to help technicolor in the same way.

Minimal Walking Technicolor

- $\mathcal{G}_{TC} = SU(2)$, & 2 adjoint fermions
- Attracted considerable theoretical interest
- Gauge coupling unification
- Dark Matter Candidates

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Lattice Technicolor

- Non-perturbative problem
- Increasingly active field in recent years
- Attention to many different theories N_f, N_c, R.
- Two approaches
    - Running Coupling (SF Method)
    - Spectrum Measurements
- Several studies of MWT. Some evidence for novel behaviour.
- Bulk phase transition $\beta \sim 2$

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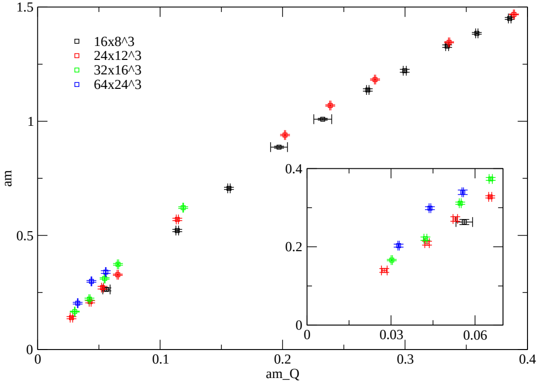
Framework

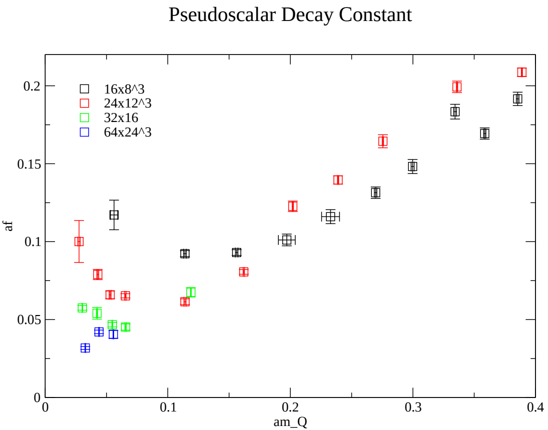
- Complements previous work
- Wilson fermions, $\beta = 2.25$
- Configs from HiRep code
- Smeared Inversion using modified Chroma
- Observables: $am_{PCAC} = am$, am_{PS} am_V, $a^2 G_{PS}$, af_{PS}, af_V

Meson Masses

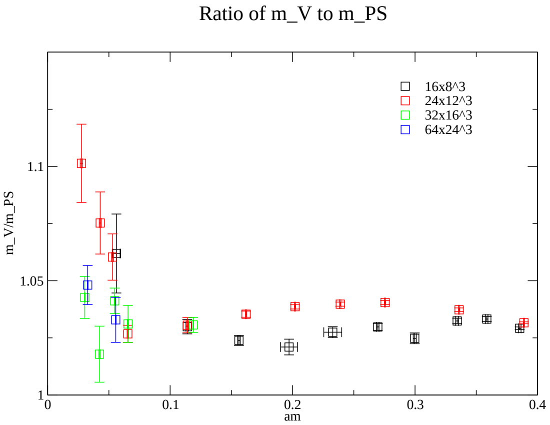
Pseudoscalar meson mass vs. PCAC quark mass



Decay Constants



Ratios

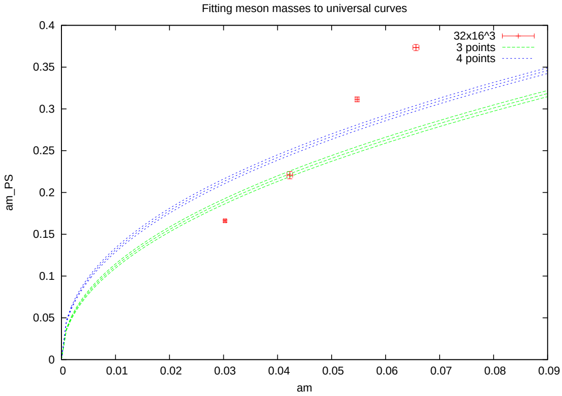

Ratio of m_V to m_PS
m_V/m_PS
am
16x8^3
24x12^3
32x16^3
64x24^3
1
1.05
1.1
0
0.1
0.2
0.3
0.4

Anomalous Dimension Fits

$$M_X \sim m^{\frac{1}{1+\gamma}}$$

- In a conformal scenario all observables of mass dimension one are expected to scale together (hyperscaling).
- Initial fits of masses to universal curves suggest $\gamma \leq 0.5$

Fitting Anomalous Dimensions



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Summary

- MWT is an interesting Yang-Mills theory could help Technicolor avoid EW & Flavour constraints.
- Indications of novel near-conformal dynamics
- Preliminary simulations must be extended in order to gain additional precision.

Future Work

- Complete scaling analysis
- Evaluate MWT contribution to S